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The Electrical Transmission to the Utica Mine.

BY J. FRANK GURNEY.

IN and about Angels Camp, Calaveras county, Cal., are a group of gold mines among which is the famous Utica mine that for years has annually produced between five and six million dollars in gold, thus earning for it the enviable distinction of having the largest output of any gold mine in California. The high price of fuel made power an expensive commodity at the Utica mine and as far back as in 1893 the progressive owners of the properties began to investigate the possibilities of utilizing electrically transmitted power, with the result that in January, 1895, a comparatively small plant was erected, first in order to secure satisfactory lighting at the most reasonable cost, and second, that greater familiarity with the applications of electricity might be obtained, not only by the management, but also by the miners themselves. This original plant was located in a modest power house, the exterior and interior of which are shown in Figures 2 and 3, and though the installation was simple in the extreme, it fulfilled its mission so admirably that it proved to be the forerunner of the interesting transmission about to be described. In passing, it may be stated that the original installation contained one 75-kilowatt, 2500-volt single-phase Westinghouse alternator, direct-driven by a six-foot tangential water wheel operated under a head of 570 feet. The line consisted of about 1000 feet of No. 1 B. & S. gage, hard drawn copper, and the distribution was entirely in incandescent and constant potential alternating current arc lighting in and about the mills.

POWER HOUSE OF THE ANGELS-UTICA TRANSMISSION.

The new installation is owned and operated by the Angels Electric Light and Power Company, a distinct corporation from the Utica Gold Mining Company and the Hobart Estate Company, although its stock is held by the last named companies. Its power house is situated

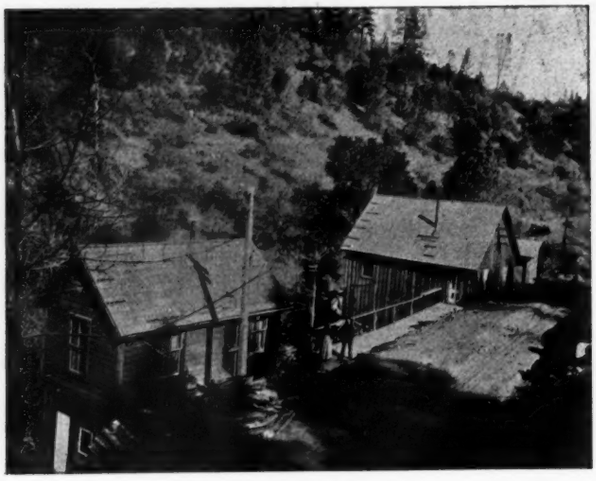

FIGURE 2.—ORIGINAL POWER HOUSE OF THE UTICA MINING CO.

about eight miles in an air line northeast of Angels Camp and about one and one-half miles east of Murphys. Water for the operation of the plant is obtained from the ditch of the Union Water Company, also owned by the Utica and Hobart Estate companies, and its reservoirs are situated in Silver Valley, Alpine county, where a reserve capacity of 1000 miners inches for 70 days is available. During the greater part of the year the water is taken out of the north fork of the Stanislaus River, the reservoirs being drawn from only when the flow of the river decreases to an amount less than that necessary for the operation of the plant. A flume 5¾ miles long takes the water from the river and delivers it to a ditch that is 20

FIGURE 3.—INTERIOR OF THE ORIGINAL POWER HOUSE OF THE UTICA MINING CO.

miles in length. This ditch terminates in the penstock, which is noteworthy in that it is divided into two compartments that are so connected by gates that either compartment may be drained and cleaned without shutting the plant down. Each of these compartments is connected to the main pipe line through its respective upper leg of the "Y" that is placed at the upper end of the pipe line. The pipe line is 1550 feet in length, with diameters ranging from 36 inches at the top to 28 inches at the bottom. The true head is 536 feet, and the effective pressure at the wheels is 225 pounds per square inch.

The power house is a substantial structure of lava built on bedrock, and all foundations are of dyke laid on bedrock in strong cement. The building at present measures 50x37 feet, with one end unfinished to allow of an addition being added to accomodate more generators. As it stands at present the plant is arranged to house only the two complete units that are now installed.

These units each consist of a 750-kilowatt, 500-volt, two-phase, 7200-alternation Westinghouse revolving armature type alternator, running at 400 revolutions per minute from a 1200-horsepower Pelton water wheel by direct connection; two 375-kilowatt, oil-insulated transformers stepping up from 500 volts two-phase to 16,500 volts three-phase; a separately-driven exciter, together with the usual

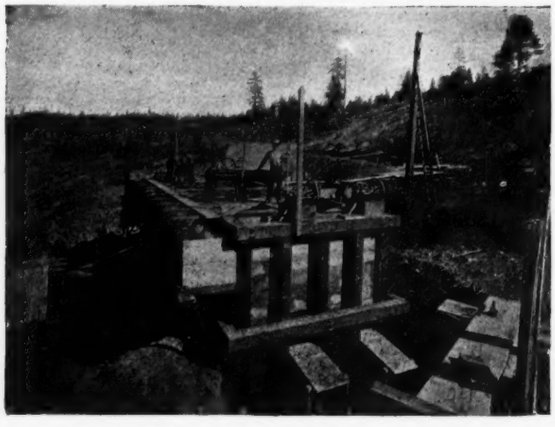

FIGURE 4.—DIVIDED FOREBAY AT THE HEAD OF THE PIPE LINE.

forms of switchboard panels, high-tension switches and fuses and the Wurts non-arcing lightning arrester system. When completed, the power house will contain three such units. In addition to the transformer equipment given above, one special transformer has been installed for use in emergencies. This special or spare transformer is so arranged that it can be substituted for any other step-up transformer should it become necessary.

If it be necessary to cut out transformer *B*, the three main switches through which its secondaries are thrown on to the main high-tension busbars are opened and the five switches connecting the secondaries of the special transformer to the same busbars are closed, and power is delivered to the line as before. The spare transformer may be run in parallel with either transformer *A* or *B* and ordinarily the load may be transferred from any transformer to the spare transformer without interruption to the service. The spare transformer is of the same capacity as the standard ones and its distinguishing feature rests in the fact that its secondary carries four taps from which are taken two 100 per cent., one 50 per cent., and

one 86.7 per cent. leads. The wiring and switches for the same appear supported on timbers imbedded in the wall back of and above the bank of transformers shown in Figure 6.

The line consists of No. 1 B. & S. gage hard drawn copper, and the wires are strung on one side of the pole

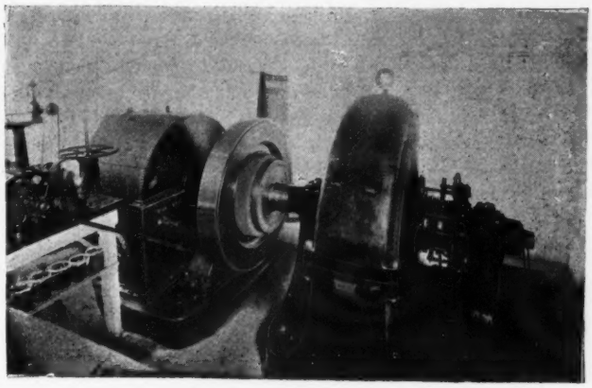

FIGURE 5.—WATER WHEELS, GENERATOR AND WATER-WHEEL GOVERNOR.

to allow of a second line being built at some future time. Triple-petticoat glass insulators, guaranteed to stand 25,000 volts are used, and the pins are of eucalyptus boiled in paraffine. All cross-arms are painted with P. & B. paint. The poles are set 40 to the mile, and are 30 feet, 40 feet, and, at road crossings, 50 feet in height.

The sub-station at Angels Camp contains lightning arresters, high-tension switches and fuses controlling all the high-tension feeder circuits for the mines operated therefrom; also high-tension switches and fuses for the sub-station transformers, which at present consist of two three-phase to two-phase, 75-kilowatt, Westinghouse air-cooled, oil-insulated 15,000 to 400 volt transformers, supplying current to a 150-horsepower, type "C" induction motor driving the Stickle mill; two three-phase to two-phase 150-kilowatt lowering transformers of the same class as the above but reducing from 15,000 to 2000 volts for supplying current for the operation of a 150-horse-

FIGURE 6.—RAISING TRANSFORMERS AND STATION WIRING.

power, type "C" Westinghouse motor at the Utica mill and also furnishing 150 kilowatts for the operation of the alternating current arc and incandescent lighting of the town of Angels Camp. These local lighting circuits are controlled by a separate switchboard located in the sub-station. Four other 75-kilowatt transformers, accompanied by four booster transformers, are also installed and are delivering power to the Calaveras lines of the Standard Electric Company of California for the lighting of San Andreas, Mokelumne Hill, Jackson, Sutter Creek, Amador City and smaller towns.

From the sub-station at Angels Camp another three-phase line is run to the Lightner mine where a 100-horse-power, type "C" Westinghouse induction motor drives a 40-stamp mill and a 150-horsepower induction motor of the same type and make drives an air compressor from which is operated all hoists and drills used in the Lightner mine. A second high-tension line runs from the sub-station to the Gold Cliff mill of the Utica company and supplies power through lowering transformers to a 75-horsepower, 400-volt, type "C" induction motor that is used for running the 40 stamps and concentrators in the mill. All these installations are highly successful in every way.

The entire installation was placed under the supervision of C. E. Heise, engineer of the San Francisco office of the Westinghouse Electric and Manufacturing Company.

Transmission

LINE LEAKAGE AND CHARGING CURRENTS.

BY PROF. W. E. GOLDSBOROUGH.

TODAY it is a confirmed fact that power can be electrically transmitted at 40,000 volts with certainty of successful operation. At this pressure all difficulties of insulation, line leakage and lightning protection have been overcome even in climates offering the most adverse conditions. The matter of line insulation, indeed, has so far advanced that no trouble need be apprehended from this source, even when laying out plans for the use of exceptionally high voltage. A few years ago there was not an insulator on the market that would stand a test pressure of 25,000 volts, whereas now factories are turning out materials capable of withstanding a continuous test at a voltage many times this value. As the demands of practice become the more exacting it can reasonably be expected that the art of insulator construction will keep pace with such demands—judging the future by the past.

As the pressure of a transmission line is increased, the line insulation is less and less affected by weather conditions. If insulators under favorable laboratory conditions withstand the high voltage test, they will probably give ample satisfaction when installed on the line, as the energy dissipated by leakage over a damp insulator quickly dries it and a further accumulation of moisture is curtailed by the electrostatic repulsion of the vapor particles.* The full pressure should never be suddenly thrown on a transmission line that has been out of use; instead the circuit should be closed when the generators are only partly excited, and the voltage gradually built up. By following this plan, the line is dried out before the maximum voltage is reached and the danger of a breakdown is greatly reduced.

A formidable obstacle to very high voltage transmission presents itself in the form of leakage of energy between adjacent lines after a pressure of 60,000 volts has been reached. This effect has been studied chiefly in latitudes in which the humidity is relatively high, where but a poor indication is given of that which is to be expected under more favorable conditions. That leakage would

*See "Moisture on High Tension Insulators," by Lieut. W. Stuart Smith in the JOURNAL for September, 1898; Vol. VI, page 57.

in any wise prove a hindrance in dry atmospheres is much to be doubted, as the dielectric strength of air improves greatly when it is freed from foreign matter and in a pure state to sustain electrostatic stress. In latitudes where it is necessary constantly to combat heavy rain and snow storms, leakage has not proven serious at 40,000 volts, and the experiments so far reported point to the fact that in almost any climate energy can be successfully transmitted over lines at 100,000 volts pressure with a leakage loss not in excess of 250 watts per mile when wires are strung on parallel pole lines upwards of 20 feet apart. Under these conditions the line would have an impedance factor of something like one and one-third. The transmission of 10,000 kilowatts 100 miles under these conditions at 100,000 volts would entail a leakage loss of only a fraction of one per cent. However, on the other hand, if only 1000 kilowatts were transmitted, the leakage would remain about the same in amount and be from two to three per cent. of the power transmitted.

The laws governing the loss of power by leakage currents between wires through the air have not been sufficiently studied to enable the formulation of any definite rule further than that the leakage from wires of small cross-section is greater than the leakage from wires of large cross-section, other things being equal, and that if wires are installed having diameters not less than 0.15 inch or greater than 0.75 inch, the leakage current will lie between 100 and 300 watts per mile when the relation between the voltage impressed on the system and the distance between wires is made to conform to the formula:

$$V = 40 + \frac{D}{4},$$

in which V is expressed in kilovolts and D is the distance between the wires expressed in inches.

In considering the transmission of power at high voltages there is another item that must not be lost sight of in determining the most economical voltage to employ; namely, the charging current that is present in every transmission system but which is usually too small to be recognized. If, for instance, it is wished to transmit 1000 kilowatts 25 miles at 10,000 volts, the charging current will amount to about half an ampere if a low frequency current is employed, while the power current will be upwards of 100 amperes. In this case the charging current has an insignificant value. If, however, the same transmission is attempted at 100,000 volts, the charging current will rise to five amperes while the power current will fall to ten amperes. Here a different state of affairs is presented. The charging current is not a wattless component of the line, in the ordinary sense of the term, but is in *advance* of the impressed electromotive force by less than 45 degrees; it, however, constantly decreases in amount as points on the line more and more remote from the generating station are attained. It, of course, dissipates power in heating the line, although not the amount its initial value would indicate, but more particularly it calls for a current capacity in the generating station in excess of what would be required by the power current alone.

To further illustrate this point: Consider a transmission line conveying 1000 kilowatts of energy at a low frequency and at 100,000 volts to a distance of 100 miles. The power current will still be 10 amperes, as in the preceding instance, but the charging current, which will be upwards of 20 amperes, will necessitate the installation of machinery rather to the end of taking care of the charging current than of taking care of the power current. But again, 10,000 kilowatts transmitted under like conditions would put the charging and power currents in the ratio of 20 to 100 and present a much more economical relationship.

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"I have found a single number of the JOURNAL to be worth the price of a year's subscription."—*Stephen D. Field, Stockbridge, Mass.*

Operation

G. E. INDUCTION POTENTIAL REGULATORS.

INDUCTION potential regulators designated as the "IR" type of the General Electric Company, were briefly referred to in these pages for November last,* supplementary to which the additional information as follows will be of value as more fully explaining the principles of operation of a prominent form of one of the most important types of apparatus that is destined to become of the greatest utility in alternating-current distribution. These regulators, which have been used principally in connection with rotary converters but which are equally adapted to single-phase lighting or power circuits, are built for any desired number of phases, those built by the General Electric Company being designated by the type letters IRS for single-phase, IRQ for two or quarter-phase, and IRT for three or six-phase regulators.

The G. E. induction regulator has a primary and a secondary winding, one of which is connected in series, and the other being

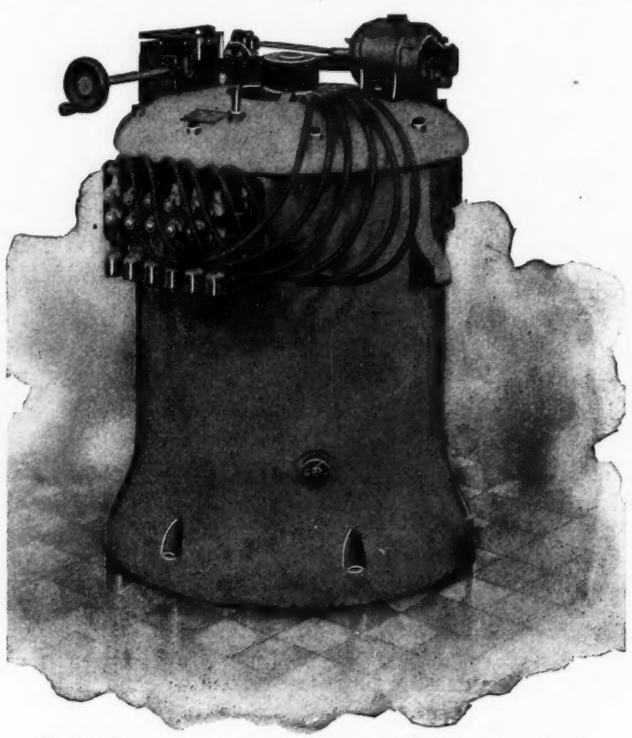

FIGURE 1.—G. E. INDUCTION POTENTIAL REGULATOR WITH MOTOR CONTROL—SIX-PHASE.

connected in shunt with the main circuit as shown in Figure 2. The voltage generated in each phase of the secondary winding, as the series coils may be termed, is constant, but by varying the relative positions of the primary and secondary, the effective voltage of any phase of the secondary on its circuit is varied from maximum boosting to zero and to maximum lowering.

Referring to Figure 3 which represents graphically the voltage of a single phase of the regulator,

$e\ o$ = generator voltage or the electromotive force impressed on the primary;

$a\ o$ = electromotive force generated in the secondary coils, and is constant with constant generator electromotive force;

$b'\ a'$ = secondary electromotive force in phase with the generator electromotive force;

$e'\ a'$ = line electromotive force, or resultant of the generator electromotive force and the secondary electromotive force.

*The JOURNAL, Vol. VIII, page 119; figures 2 and 4 in the above are reproduced therefrom.

The construction of the regulator is such that the secondary voltage *o a* is made to assume any desired phase position relative to the primary electromotive force, as *o f*, *o b*, *o c*, etc. When its phase relation is as represented by *o f*, which is the position when the north poles and the south poles of the primary and secondary windings are opposite, the secondary voltage is in phase with the primary voltage and is added directly to that of the generator. The regulator is then said to be in the position of maximum "boost," and by rotating the armature with reference to the fields, the phase relation can be changed to any extent between this and directly opposed voltages. When the voltage of the secondary is directly opposed to that of the primary or generator, its phase relation is as represented by *o d* in the diagram, while *o b* represents the phase relation of the secondary when in the neutral position.

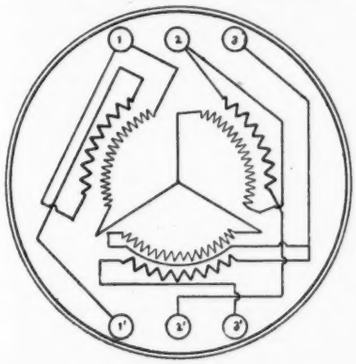

FIGURE 2.

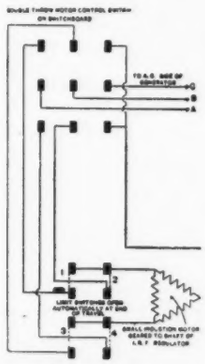

FIGURE 4.

In order to avoid the trouble experienced in adjusting the voltages when each phase is controlled independently, the polyphase potential regulators are arranged to change the voltage in all phases simultaneously.

The regulators can be arranged for either hand or motor control. When operated by hand, the movable core is rotated by means of a hand wheel and shaft. When it is desired to operate the regulator from a distance, the apparatus is fitted, in addition to the usual hand wheel and shafts, with a small motor which is arranged through suitable gearing to turn the movable core. This motor may be either a direct current or an induction motor, and is fully controlled by a small double-pole, double-throw switch mounted at the switchboard or other convenient place. Throwing the switch up or down will move the regulator so as to raise or lower the voltage as may be desired, and when the correct line voltage is obtained, the regulator may be stopped by opening the switch. The circuit connections for this controller are shown in Figure 4.

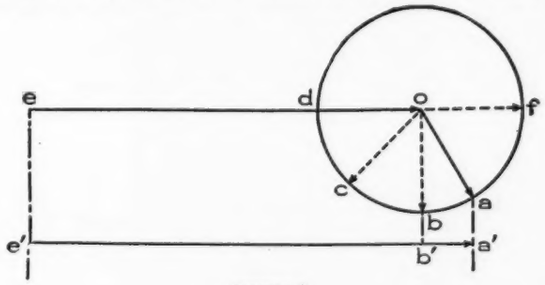

FIGURE 3.

In order that the regulator may stop on reaching the limits of regulation when moving in either direction, it is provided with a limiting switch which opens automatically. This automatic opening, however, does not at all interfere with the movement in the opposite direction, which the operator may produce by reversing the controlling switch.

The winding of both primary and secondary is a distributed or induction motor type of winding, and can be arranged for any number of phases. These regulators have been built for single, two, three and six phase circuits.

In electrical design the induction regulator is very similar to that of G. E. induction motors, the copper conductors being first formed, then thoroughly insulated and laid in slots in the movable and stationary cores. The primary is placed on the movable core and has either a closed delta or a "Y" winding, while the secondary or stationary winding is placed on the stationary core and is an open winding, each section or phase being connected in series with the corresponding phase of the line, the voltage of which is to be controlled. The connections from the terminals to the primary winding consist of flexible cables; there are no sliding contacts. The maximum arc through which this primary moves is 90° in a four-pole machine and 60° in a six-pole machine, or one polar space, the small movement of the primary permitting the use of flexible leads instead of sliding contacts as connections to the winding.

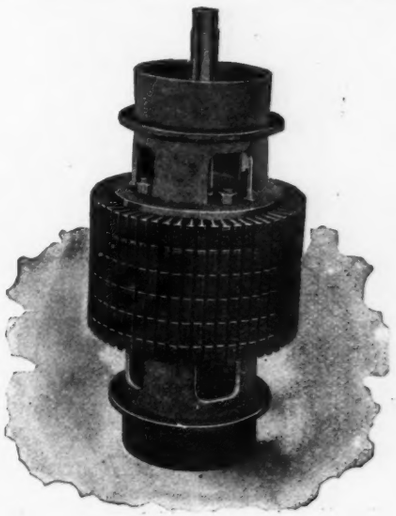

FIGURE 5.—MOVABLE CORE.

The several distinctive features in the mechanical design permit the manufacture of machines of very graceful lines as shown by the accompanying illustrations. The movable core and winding is mounted on a vertical shaft, the upper end of which projects through the cover. To this small shaft is fastened a segmental worm gear, which meshes with a worm on the small operating shaft. On this operating shaft is placed a hand wheel, and when the regulator is provided with the motor control, the shaft is extended to accommodate the motor gearing.

While the efficiency of the induction regulator is somewhat

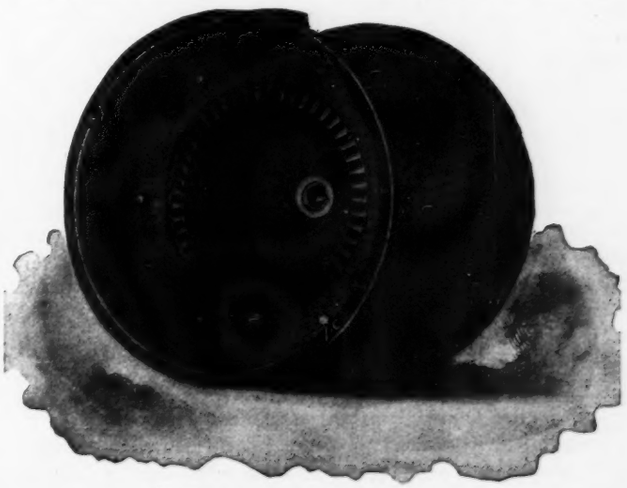

FIGURE 6.—STATIONARY CORE.

higher than that of the average induction motor of the same capacity, the regulator has no moving parts to create an air circulation, and therefore cannot be readily made self-cooling and retain the same compact form, except in the smaller sizes.

Regulators have been made self-cooling by the use of oil in sizes up to eight kilowatts. Figure 7 shows an 8-kilowatt, 25-cycle, three-phase regulator which is entirely self-cooling. The ribs cast

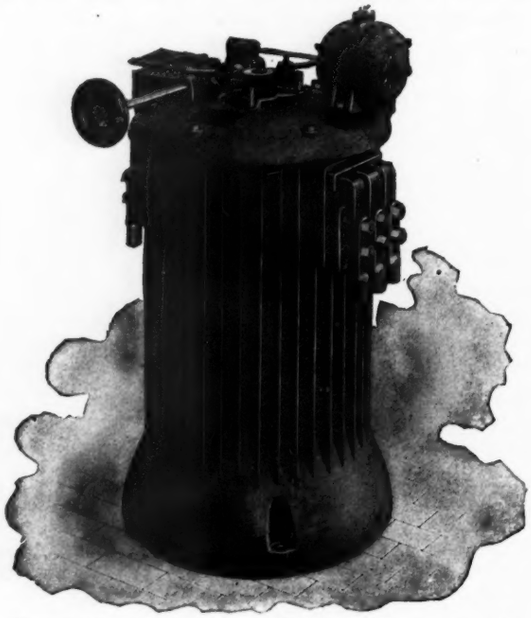

FIGURE 7.—SELF-COOLING INDUCTION POTENTIAL REGULATOR.

on the outside of the tank serve the purpose of increasing the radiating surface sufficiently to maintain a low temperature when the regulator is running at full load. Artificial cooling is accomplished by means of a forced draft of air or by cooling coils through which cold water is circulated.

In stations in which air-blast transformers are installed, this method of cooling is recommended by the General Electric Company as no separate blower outfit is necessary, the regulator receiving its supply of air from the same source as the transformers.

In regulators which are cooled by forced air blast, the air enters through an opening in the base, the heated air escaping through the top. Such regulators are provided with an air damper placed in the bottom of the box or tank to control the amount of air for cooling. The opening of the damper is indicated by an index.

Water-cooled regulators are preferable in stations not equipped with air blast transformers but having a cold water supply. The external appearance of a water-cooled regulator is similar to that of one cooled by air. The tank contains a sufficient amount of insulating oil to cover the winding and water pipes. The pipes are placed in the upper portion of the regulator so as to more effectually cool the heated oil.

Owing to the great variety of conditions and the range of capacity for which induction regulators have been built in the past, no standard line has been developed by the General Electric Company, but they can be built for any desired capacity and frequency and for any primary voltage up to, approximately, 3000 volts. The secondary can be wound for very heavy currents. Standard parts have been designed for such regulators which admit of their manufacture to meet almost any condition of service.

NOTICE TO MEMBERS OF THE PACIFIC COAST ELECTRIC TRANSMISSION ASSOCIATION.

The Fourth Annual Convention of the Pacific Coast Electric Transmission Association will be held at "The Tavern," summit of Mount Tamalpais, Marin county, Cal., commencing Tuesday, June 19, 1900. A full attendance of members is requested.

Distribution

ROTARIES FOR CHARGING AUTOMOBILE BATTERIES.

THE peculiar topography of California and the rapidly increasing popularity of electromobiles, together with the fact that long country runs must soon become a favorite sport with those who "bubble," as automobiling is fast becoming to be facetiously termed, will probably make it necessary for electric lighting and power plants as well as transmission companies operating along the country highways to provide means for charging the batteries of electromobiles under conditions that will involve but slight trouble to the station attendant, while giving variable voltages as may be required in the exigencies of charging or in the number of storage cells used.

A form of apparatus that fully conforms to these requirements has been brought out by the Westinghouse Electric and Manufacturing Company, and its extreme utility strikingly illustrates the advantage of having the various elements of a combined set of apparatus harmonize properly. It converts alternating current supplied by a local electric company into direct current for charging storage batteries. Two-phase alternating current of 7200 alternations, at a voltage of 100 to 110, has to be converted into a

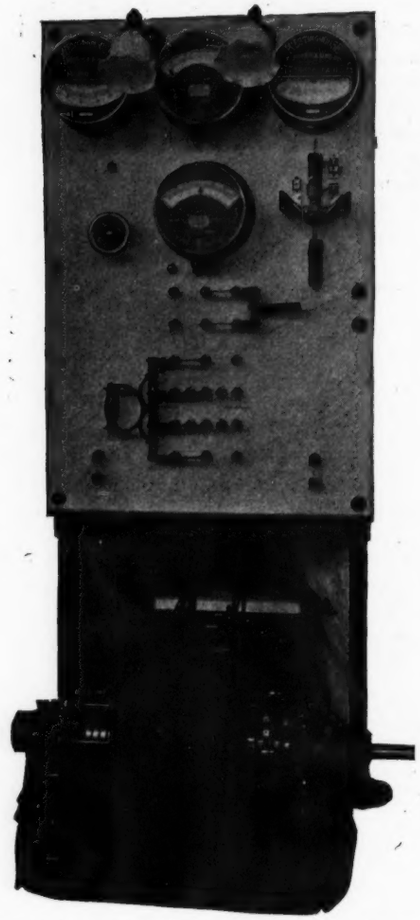

FIGURE 1.—ROTARY CONVERTER AND SWITCHBOARD FOR CHARGING AUTOMOBILE STORAGE BATTERIES.

direct-current voltage varying from 90 to 140 volts, which is effected by suitable adjustments. The outfit consists of three elements: The rotary converter; two autotransformers, one in each phase, and the switchboard.

The rotary converter transforms alternating into direct current, the ratio of transformation being such as to give a direct-current voltage approximately one and four-tenths (1.4) times the alternating. If the alternating-current voltage is 100, then the direct-

current voltage will be 140. To obtain a lower direct-current voltage, it is necessary to reduce the voltage of the alternating current by autotransformers. In order to start the rotary satisfactorily, a low voltage must be applied; this is also obtained from autotransformers. The rotary converter delivers nominally 110 volts at practically constant electromotive force. The maximum current will be 60 amperes for about half an hour, when the current is gradually diminished to about 10 amperes at the end of

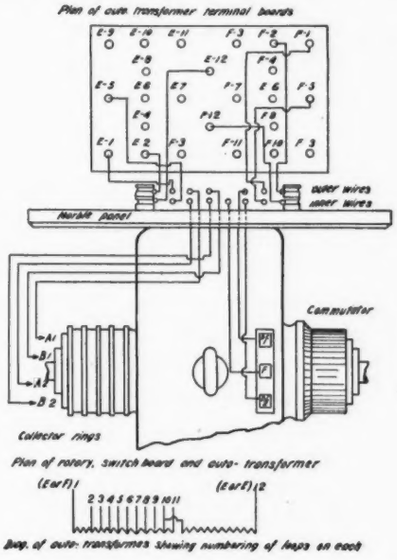
Plan of auto transformer terminal boards
outer wires
outer wires
Switch board
Commutator
Collector rings
Plan of rotary, switch board and auto- transformer
(Earth) 1
(Earth) 2
1 2 3 4 5 6 7 8 9 10 11
Dup. of auto: transformer showing numbering of taps on each

FIGURE 2.—PLAN OF AUTOTRANSFORMER TERMINAL BOARD.

about three hours. The rotary is adjustable by means of a field rheostat so that the electromotive force may be reduced from 110 volts to 95 volts. By changing to other loops on the lowering transformers the electromotive force delivered may be changed from 110 to 140 volts. When running at 140 volts the electromotive force may be lowered by means of a rheostat to 125 volts. The rotary is started by throwing a low voltage directly on the armature, and for this purpose suitable loops are provided from the autotransformers. The rotary delivers direct current as a direct-current generator, but at several voltages varying from 110 to 140 volts. The electromotive force is in each case capable of being reduced 15 volts by means of a field rheostat.

The two autotransformers serve three purposes: (1) They reduce the line voltage to a pressure suitable for starting the rotary; (2) They furnish a voltage which, applied to the rotary, gives a direct-current voltage suitable for charging the storage batteries; (3) They introduce into the circuit self-induction of such an amount as permits a variation in the electromotive force of the rotary by a simple adjustment of the rheostat.

The autotransformers have a number of loops so that with either 100 or 110 volts on the primary, the rotary may deliver 105, 110, 115, 120, 130 or 140 volts. The coil is provided with a number of terminals in the form of binding posts, placed at the transformers to which the wires to the switches may be connected. This is to secure certain fixed adjustments, and not to vary the voltage from the autotransformers while the rotary is running.

The switchboard is provided with a double-throw switch for starting and running the rotary, with a double-throw switch for connecting the direct current to the battery, also with a circuit breaker for opening the direct-current circuit in case the current is too great, with ammeters for measuring the alternating current in each phase, with an ammeter for measuring the direct current, and with a voltmeter for measuring the voltage supplied to the battery. Fuses are placed in the alternating-current circuit for opening the circuit in case the current becomes too great. A rheostat enables the voltage applied to the battery to be varied over a small range.

The rotary stands in front of the board, as shown in the illustration, with the autotransformers at the back of the board. In order to start the rotary it is necessary to open the circuit breakers and all switches on the board, and turn the rheostat handle to the right as far as possible, thereby opening the field circuit, and then throw the large four-pole switch to the right. When the rotary has reached synchronism, the rheostat handle is turned to the left, thereby closing the field, and the field strength is adjusted until the alternating-current ammeter registers a minimum, and the large four-pole switch is then quickly thrown to the left, when, if all connections are right, the rotary will run at a synchronous speed.

The rheostat should be adjusted again so that the current indicated by the alternating-current ammeter is a minimum. The direct-current voltage can then be raised or lowered from 5 to 10 volts by varying the rheostat, which will increase the alternating current. The electromotive force, when the alternating current is a minimum, should be about five volts less than the maximum required for charging the battery.

When the rotary is running and ready for operation, the circuit breaker should first be closed, and then the double-throw direct-current switch should be closed in the direction indicated by the voltmeter. A small load of incandescent lamps should be placed between the binding posts from which the leads are to be taken to the battery. If the direct-current ammeter deflects in the wrong direction, the leads to it should be reversed. All is then in readiness for applying current to the battery. When the battery is charged the circuit breaker is to be opened by hand, the double-throw switch is to be opened together with the four-pole switch, and the rheostat should be moved to its extreme position.

It will be perceived by the illustrations accompanying this article that the outfit forms a complete whole, and all parts harmonize properly. By the arrangement adopted, the incoming wires are carried to the top of the switchboard, and the outgoing wires to the battery, from the side of the board, and the wires to the autotransformers and the rotary are taken from the bottom of the board in the form of flexible cables, all having proper lengths and being adjusted for the terminals to which they are to be connected.

AFTER THE BATTLE.*

TO H. H. B.

Earth celebrates her brave who dauntless go
With stir of drum and trumpet's heartening blare,
To face on battlefield life's final foe,
And find, 'mid proud acclaim, death sweet and fair.

Not thus *he* met the fray—this heart of gold!—
Who, worn of slow disease, and scant of breath,
With steadfast front, and pulses calm as bold,
Looked smiling in the ruthless face of Death!

The hard day won, Night cometh: on her breast,
With sooth mandragora, she stills him now:
So mothers rock their wearied babes to rest
With tender kisses pressed on lip and brow.

* * *

The rose is dead! Even so; yet have we had our summer, heart—
Our summer time, warm, loveful, sweet! Come weary winter then,
We will not flout at Fate; but brave pain's cruel smart,
And smiling cry. Well worth is life—a rose hath been!

*From "The Search of Ceres," a book of exquisite poems by Sarah Warner Brooks. The work is inscribed to the memory of her son, Herbert H. Brooks, late general manager of the American Circular Loom Company, and the announcement of whose death, after a lingering illness, as chronicled in the JOURNAL for August last, stirred the sympathies of the myriad of his friends in every avenue of the electrical business.

The tender lines thus given to the memory of a loving and devoted son are an offering from the warm floods of a mother's heart.—THE EDITOR.

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EDITORIAL.

SIMPLIFICATION OF INTERIOR WIRING.

The presidential address of Professor Silvanus P. Thompson before the Institution of Electrical Engineers, held in London in December last, is a paper that fairly bristles with opinions upon the trend of present electrical tendencies. That these opinions are sound goes without saying, for S. P. Thompson has uttered them. That they cover almost every branch of electrical engineering from telegrapy to transmission is also to be predicted; and that they are well worthy of more than passing consideration is as self-evident, both for the same reason. Let us discuss one of his most sapient observations.

The competition of electricity with gas as a means of illumination has, as we all know, been rendered very severe during recent years by the development of incandescent gas lighting, and while the discovery of the properties of the rare earths in giving augmented illumination—the result of a purely scientific research—was the foundation of the invention of the Welsbach mantle, it is singular that the very same properties were not turned to account in electric illumination before the invention by Nernst of the incandescent electric lamp which bears his name. Electrical engineers are still waiting expectantly for the commercial introduction of the Nernst lamp, which it is almost safe to say, will not effect an upheaval in existing methods of artificial lighting to a more pronounced degree than did the invention of the incandescent lamp. Revolutionizing inventions are indeed few and far between, and he is wise whose judgment is not skewed by the bare announcement of scientific discoveries which savor of them. Professor Thompson gives evidence of fully appreciating this truth when he points out that a far more important factor in the economic struggle between rival lighting methods than the commercial perfection of the Nernst lamp remains in a possible reduction of the high prime cost of the electric wiring of buildings.

Here is offered a suggestion that is so modest and so axiomatic that its very simplicity may give rise to a diffidence in the minds of electrical engineers (incongruous though diffidence and electrical engineering may be) that may be hard to overcome. The station manager will say that it is all right enough to reduce the cost of interior wiring provided the present high standards of safety and service are not reduced, and then he will self-complacently add, "But how are you going to do it?" Professor Thompson's idea is that could electric house wiring be carried out as simply and as cheaply as the putting in of gas pipes, an enormous growth of the electric lighting business might be confidently expected, but so long as station engineers and boards of fire underwriters insist on having both wires fully insulated, and do not allow an uninsulated or a semi-insulated return conductor, so long will this growth be delayed. "With the introduction of armored conduits for interior wiring," says Professor Thompson, "surely the prejudice which requires a double insulator will disappear."

Before the suggestion just given toward the simplification of house wiring is dismissed, it will be well to reflect upon present practices in regard to interior wiring. It has long since been pointed out that the mere testing of the insulation resistance of a wiring system only gives a comparative idea of the condition of the circuits between wire and wire and between either wire and the ground *at the instant of test.* A recent issue of a London contemporary* goes into the subject more fully than this by showing what the insulation test, as ordinarily applied, does *not* reveal.

It gives absolutely no indication as to

1. Quality of insulating material on conductors;
2. System on which wiring is carried out;
3. Capacity of conductors;
4. Whether joints are properly made or not;
5. Whether fuses are inserted where necessary;
6. Whether fuse wire is properly proportioned to current which may safely pass;
7. Whether conductors are bunched or not;
8. Whether conductors are protected in any way from mechanical or other injury;
9. Whether fuses or conductors are accessible in case of injury or breakdown;
10. Whether there is a break in continuity in the conductors.

It might be added with propriety that six of these ten items constitute points that can not be passed upon without a visual examination of each and every portion of the wiring system. Professor Thompson's suggestion will reduce the hazard under item 1 by 50 per cent.; on item 2 it will eliminate the hazard because it will provide the simplest, easiest and cheapest system of interior wiring which it will be to the obvious advantage of contractors

*The Electrical Review, Vol. XLVI, page 306, February 23, 1900.

to adopt; it will eliminate 50 per cent. of the hazard from fuses under items 5 and 6 by reducing their number by half; it will eliminate by 50 per cent. the hazard of bunching wires under item 7 by making the bunching of the wires of one of the polarities an expensive and extravagant indulgence; and finally, it will minimize troubles which arise under items 8 and 10 by the simple and efficacious remedy which is at hand in the grounding of the single-wire side of the system at frequent intervals.

These ideas are radical, but the statement that they are irrational can not be defended.

The largest steamship afloat, the Oceanic, is wired strictly along these lines, its hull being depended upon for a return circuit on the negative side of the system.*

Moreover, should it not occur to the wiring engineer that the carrying out of Professor Thompson's suggestion is at worst but the rationalization of the Edison three-wire distribution, 90 per cent. of which in central-station work is carried on with a grounded neutral?

The vast majority of incandescent electric lighting from central stations in America is done from Edison three-wire distributions with these self-same grounded neutrals. Of what earthly or other use to central stations, to fire underwriters, to man or to mammon, are the countless tons of insulation which covers the countless leagues of interior wiring that is in direct electrical connection with grounded neutrals?

MAN'S AND NATURE'S HANDIWORK.

The recent comment in these columns on the microscopic values of energy as found in some applications of electricity, notably in the case of the energy of telephone and coherer currents,† finds a parallel in a mechanical sense in experiments recently made to determine the amplitude of vibration in the diaphragms of telephone receivers. The results of these experiments were embodied in a paper recently read before the British Physical Society and editorially commented on in an American electrical contemporary‡ which states that it is well known that a telephone receiver may be uttering strident tones and yet no vibratory movement of the diaphragm will be perceptible either to the touch or to the eye. In fact, some observers have gone so far as to declare that the telephone diaphragm never vibrates in the same sense that the tympanum of a bass drum vibrates, and that the vibratory movement in the telephone diaphragm is entirely molecular. Sensitive optical methods have, however, been tried at different times, which appeared to indicate that there was at least some bodily vibration of the disc.

In the measurements described in the paper, the method was purely mechanical, although checked by optical means. A screw of half-millimetre pitch, with a graduated head, was capable of adjustment to $\frac{1}{5000}$th of a turn. Such an angular unit represented, therefore, an advance of about four-millionth of an inch ($\frac{1}{10000}$th millimetre). The screw passed upon a triple set of levers minifying jointly in the ratio $\frac{1}{100}$, so that the final tip was advanced one twenty-fifth of a millionth of an inch for the unit of angular screw motion. The tip was brought into play over the center of a telephone diaphragm, and acted to the latter as a relay lever acts toward its contact stop. The screw was adjusted until a receiver in the circuit indicated that the tip was just touching the diaphragm. Measured currents of feeble intensity were then sent through the telephone, buckling the disc very slightly, and requiring a small advance of the screw and tip, to re-establish electric contact. By this means the amplitude of motion of the center of the diaphragm corresponding to a series of measured steady currents was found and plotted in a curve. By measuring the virtual or effective strength of telephonic alternating currents, the amplitude of vibration corresponding to those currents was taken from the plotted curve. Audible sounds in the telephone corresponded to about fifteen-billionth of an inch. "Comfortable" sounds corresponded to about two-millionths of an inch, and "uncomfortable" sounds to forty-millionths of an inch.

As a matter of fact, telephony is a highly perfected system for the electrical transmission of power in infinitesimal values. Compared with standard transmission practices the prime mover in a telephonic transmission is found in the muscles of the larynx. Through the medium of the atmosphere, the larynx is direct-coupled to the diaphragm of the transmitter which it throws into vibration of greater or less amplitude and of varying frequency, corresponding with the modulations and tones of the speaker's voice. This diaphragm may be likened to an induction type alternator wherein the continuous currents, rather than field magnetism, are primarily affected—in one, current strength is varied by ohmic means; in the other, magnetic strength is influenced by induction means. The transmitter, with its accompanying induction coil, becomes a combined alternating current, single-phase generator and step-up transformer; the line may in each instance be considered as identical and embodying common problems as to capacity, self and mutual induction, leakage, etc.; and in the diaphragms of the receiver, whether it be a thousand feet or a thousand miles from the transmitter—that is, the "generating station"—is found the alternating-current motor whose function is to reproduce into mechanical motion the successive impulses of the speaker's voice that are impinged upon the diaphragm of the transmitter. Then if conversation is carried on "comfortably" the telephonic transmission plant, which mayhap has cost hundreds of thousands of dollars, is sending only sufficient energy to vibrate a disc of metal weighing a few grains, through an amplitude of but two-millionths of an inch!

When one appreciates the astounding ends that are being attained in fields of science, he is apt to think that man's sphere of knowledge, if not work, is becoming so amazingly enlarged that it is slowly but surely encroaching upon the domain of the infinite. He may scan the

*See the *American Electrician*, Vol. XI, page 502, November, 1899.
†The JOURNAL, Vol. IX, page 66, April, 1900.
‡*Electrical World and Engineer*, Vol. XXV, No. 17, page 610.

enormous gap in electrical transmission that lies between the tremendous energy of the Niagara plant and the equally impressive work accomplished in telephonic transmission—impressive because of its almost immeasurable minuteness—and having surveyed it all, he may feel that surely the confines of science are being reached in at least this one direction. But let him remember that the work accomplished in a telephonic transmission of power is a Niagara of energy to some other yet unknown use, and that this other application is a veritable Niagara of energy in comparison with still another possible application, and so on down the scale for ever and aye.

To go in the other direction: Niagara gives us a greater concentration of energy than any other power which it may be the fortune of man to utilize in a special industrial undertaking. Precipitation to annually cover the earth to an average depth of five feet necessitates the evaporation of a body of water estimated to be 24,000 miles long by 3000 miles broad by 16 feet deep. Were Niagara Falls 4000 miles wide, instead of but 3800 feet, they would in the course of a year at their ordinary rate of flow, deliver a volume of water practically equivalent to the quantity annually evaporated from the oceans at the torrid zone and precipitated as rain. But the water of Niagara drops only 165 feet while rain drops from 5000 to 10,000 feet. Then, the work performed by the sun in raising these thirty odd quintillions of cubic feet of water to an elevation of a mile or two is but a tithe of that it performs in the execution of other terrestrial functions. We must remember that this tithe of a Niagara of water, 4000 miles wide and much over a mile high, represents but a bagatelle of the energy of the sun, for indeed, the world's position in the solar universe is as but an atom of the earth.

Yet, when the entire energy of our little terrestrial Niagara is entirely utilized in industrial operations, how loudly will man proclaim his prowess to his fellow man!

These comparisons impress at once the boundless realms of science, and the immeasurable discrepancy existing between the Creator's handiwork and man's. Above all, they teach man to remember that he is but a finite being and that his achievements, however marvelous they may appear in his own self-conscious eyes, are but passing nonentities in the works of Nature.

Correspondence

DUST ON ELECTRIC LIGHT WIRES.

To the Editor: I have a question for your readers. Why does one of a pair of wires carrying direct current blacken (accumulate dust) more than the other?

Perhaps a little explanation may not be out of order and I will cite a case which came under my notice. The two leading wires supplying current to about half a dozen 16-candlepower lamps were supported by cleats on the ceiling near the middle, about 10 feet from the walls on either side, the room being about 20 feet square and ceiling 16 feet high. The lamps were lighted probably fifty hours per month with direct current, 110 volts. After two years one of the wires showed unmistakably darker than the other.

X.

Gas

INDUSTRIAL GAS.—XIII.

BY FRANK H. BATES.

[THE OXYGEN CALORIMETER—CONTINUED.]

PRELIMINARY to operation. Situate the apparatus to be employed so as to be nearly free from changes of temperature. Fill the calorimeter with water by means of the cup P, Figure 33,* and adjusting valve O, noting that it rises nearly to the upper end of the glass tube B. See that the nut E is sufficiently tight to prevent leakage at the insertion of the glass tube, and note that the exit L for water drainage is clear by opening the valve M for a moment. Connect the nipple J to the oxygen supply (oxygen gas is required at a pressure of 175 pounds per square inch), and see that a gage is attached directly to the calorimeter by the connection shown in the plan view of Figure 35, and graduated to read up to 250 pounds.

Insert the fuel-holder, bringing up with the nut G, having previously looped a platinum wire between the ends T and U (Figure 36) of the conducting-rod and holder-arm respectively.

By the valve K, Figure 33, admit oxygen gas until the indicated pressure by gage is 175 pounds, when close valves on both the calorimeter and oxygen apparatus.

After making certain that all connections of the calorimeter are tight, attach one wire from the electric source to the lower end of the conducting-rod T and then complete the electrical circuit by bringing in contact with the body of the instrument the other wire. A but momentary glowing of the incandescent lamps indicates with certainty the fracture of the platinum wire, assuring one that the size selected is the proper one for the current employed. Anything more than a momentary glowing is indicative of wire of too great a carrying capacity; *i. e.:* a wire of too large diameter, necessitating the substitution of a smaller one; otherwise the combustion of the fuel would be far from instantaneous, and, furthermore, the heat resulting from the continued glowing of the platinum wire due to the resistance offered to the passage of the current would cause an error to this extent in the final results.

Having made certain of proper working, the apparatus may be calibrated.

Calibration. The value in heat units corresponding to an inch of the scale D, Figure 33, may now be determined by means of a substance of known calorific value. Pure naphthaline is largely used for this purpose since its calorific value (one gram of naphthaline evolves 9690. calories per kilogramme (Berthelot) or its equivalent, 17442. British thermal units per pound) has been determined with great accuracy, and owing to the fact that it is easily procurable in the pure state. Making a preliminary test of the fuel under consideration to acquaint one with an idea of its heat value, and then selecting such weight of the fuel as will afford

*The illustrations referred to in this article will be found on pages 54 and 55 of the JOURNAL for March.

approximately the same number of heat units as contained by the sample of naphthaline used in calibration, will greatly minimize the total percentage of error since the instrument is operated through nearly the same range of temperature and under nearly the same conditions, and since, in both cases, the *cooling correction* applied is determined in precisely the same manner. That there will be some inaccuracy is undeniable, owing to loss or gain by radiation, air convection, etc., it being impossible to maintain constant similarity as regards conditions, and since the quantities tested are very small, but inaccuracies brought about through these causes will be slight; the method may therefore be accepted as reliable for engineering or other work except where great accuracy, as for scientific purposes, is required.

Since the method for calibration is similar to that pursued in testing the sample, considered in detail under *operation*, it will suffice here to state that in the present instance naphthaline gave a value of 1223 British thermal units per inch of scale, corresponding to 123.3 units per one-tenth inch (the smaller graduations).

Operation. Allow the instrument to remain standing, completely filled with water, together with the oxygen tank,* for a day or two, that the air, water, apparatus, etc., may come to within about a degree of the same temperature. Drain off by means of the valve M and outlet L sufficient water to cause the level in the glass tube B to lower to within about an inch of the nut E.

Place the fuel to be tested, after carefully weighing,† (if coal, finely powdered), in a small porcelain crucible and fix the latter securely in the fuel-holder, looping a platinum wire well into the sample and between the ends of the two rods as heretofore explained. Taking care not to disarrange any of the connections, insert the igniting device up within the inner chamber, making fast and perfectly tight by means of the nut G.

Make up the connections to the electric source, leaving the end of one wire free.

Admit oxygen by means of the valve K till the pressure as shown by the gage reaches 175 pounds.

See that no leakage results.

Bring the lowest division on the sliding scale, the zero, to the level of the *lowest point* of the meniscus, which forms at the surface of the water in the glass tube.

Note that there is but *little* fluctuation.

With a stop-watch in hand bring the free electric wire in contact with the body of the instrument, igniting the fuel, and noting the time at the instant of ignition; wait until the water column reaches its maximum height, when again note the time together with the scale reading.

Allow an interval of time equal to that occupied by the water in rising to its maximum point, when again note the scale reading which will be somewhat lower. The difference between this reading and the maximum reading is the *cooling correction*, and is added to the maximum reading.

Derivation of results. Knowing the value—termed scale constant—in British thermal units per inch of scale from the calibration with naphthaline, it is but necessary to multiply the corrected scale reading in inches and decimal parts thereof by this scale constant, in the present instance 1223., giving directly, in British thermal units the calorific value of the given weight of fuel taken. This value is readily calculated up to unit weights.

Special hints. With coal it is generally customary to carefully dry the sample of free moisture before weighing.

There will generally be found a slight discoloration on removing the crucible, due to imperfect combustion, but the quantity is so small as to hardly affect the results, the residue consisting almost entirely of ash. A correction may be applied however, by weighing the crucible together with the residue and ash, and then igniting for some fifteen minutes in the flame of a strong blast lamp, cooling in a desicator, and re-weighing, any difference in weight being due to previously unburned matter, considered as carbon, for which proper correction is now easily made.

In making use of this instrument especially note:

That the air, water and apparatus are within a degree or two of the same temperature;

That the water in the water column remains at nearly the same height after waiting a few moments for the expanding effect of the admitted oxygen gas, any tendency to rise or fall being due to a difference in temperature;

That no leakage occurs, either of water or oxygen gas, a reduction in pressure causing a change in the water volume, and, in consequence, affecting the scale reading;

That in taking the time of the rise of the water from the zero mark to the point of maximum height, to conclude the time the instant the water no longer rises, not waiting for the fall, there being a very gradual change at this point;

That the fracture of the platinum wire is nearly instantaneous.

This instrument serves for the determination of solid or liquid fuel, but not for gaseous.

(Continuation in next number.)

*Oxygen gas may be purchased in cylinders under pressure of about 225 lbs.

†The weight to be such as will afford approximately the same number of heat units as were evolved by the sample of naphthaline used in calibration. A knowledge of the quality of the fuel will generally be a sufficient guide; otherwise a preliminary determination may be made.

Industrial

In responding to advertisements in this publication kindly mention "The Journal of Electricity, Power and Gas."

TUTTHILL WATER WHEELS AND GOVERNORS.

IMPULSE reaction water-wheels have been defined as being the class of water-wheels which derive power from the pressure afforded by a head of water supplied by a line of pipe which discharges a jet upon the wheel through a small nozzle, the size of which is proportioned to the amount and head of water available and to the power required. In all such wheels, the plane of the wheel is vertical and it turns upon a horizontal axle. The bearings are mounted upon a rigid base, generally of cast iron which also supports the nozzle or nozzles, making the machine, as a whole, self-contained. The bearings are accessible at all times for examination and lubrication, and, being ordinarily of the self-oiling

*Excerpts from a catalogue lately issued by the Oakland (Cal.) Iron Works, manufacturers of Tutthill Water Wheels and Governors.

FIGURE 1.

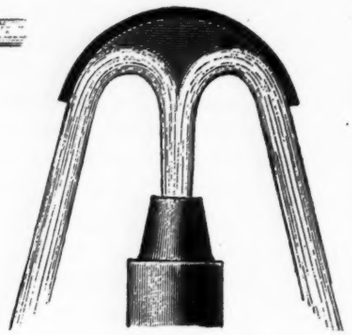

FIGURE 2.

FIGURE 3.

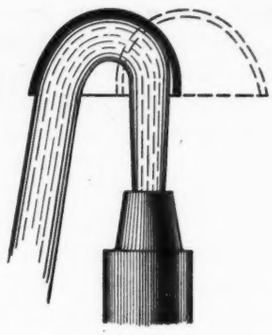

FIGURE 4.

Illustrating the action of a jet striking a flat surface, Figure 1. A simple cup, Figure 2. A divided cup, Figure 3. The Tutthill cup, Figure 4.

type, are easily protected from water and grit. Over the wheel, but free from it, is placed a housing for withholding the sling of the water from the wheel and directing it, theoretically, downward to the tail race, by means of which it is carried away. The jet is applied to the wheel tangentially, and strikes consecutively the cup-shaped buckets that are bolted or cast on to its periphery. The direction of the water takes in entering into and leaving the buckets will be discussed further on, but the result of the action is such that when the buckets are properly shaped, when the jet is properly applied, and when the speed of revolution of the water-wheel bears a proper ratio to the velocity of the jet, the energy of the moving water of the jet is converted into power deliverable from the wheel, and the water drops from the wheel by gravity, that is, without velocity, and, consequently, without energy.

There are a multitude of water-wheels of this style, all of which are variously of the jet, tangential, or impulse reaction types, and they are all the natural outgrowth of the old "hurdy-gurdy" water-wheel first used by the California miners in the 1850s.

The favor into which these water-wheels has sprung has been beyond precedent in the annals of hydraulic engineering, so that now the wheels in use are numbered by tens of thousands, and the work they are doing runs into millions of horse-power. The reasons for their great popularity and prompt adoption, in all installations wherein the head of water available is sufficient, are easily understood. Their extreme simplicity renders them strong and durable, not liable to get out of order, and enables them to be run with a minimum of wear. Breakage seldom occurs; the wear is confined to the shaft bearings and to the vane surfaces over which the water passes. There are no running-water joints to preserve, and the nozzle is of the simplest and most efficient form, the cylindrical jet being commonly used. The path of the water in the bucket is short, reducing friction to a minimum. If the water carries abrasive materials, the effect is sometimes seen on the wetted surface, but the wear is slight, and never detrimental to efficiency. Then again, some types of tangential wheels have buckets bolted on, so that one or more may be easily and quickly replaced without disturbing the installation. This is an advantage which is everywhere appreciated, especially in localities far removed from industrial centers.

The tendency of modern machine practice is strongly toward introducing direct connection between the water-wheel and the machine to be driven wherever possible, thus simplifying the parts, reducing the first cost and maintenance, and economizing space. The construction of impulse reaction water-wheels enables this to be done by so relating the diameter of the wheel to the head that the rotative speed will be that specifically required for the operation of the machine to be driven.

In the power-house of the Nevada County Electric Power Company near Nevada City, Cal., are four wheels of different diameters mounted on the same shaft, which is coupled by direct connection to a polyphase electric generator, the smaller wheel being operated under the head of 200 feet, while the head applied to the larger one is 800 feet. The minimum diameter depends, to a certain extent, upon the quantity of water available for use; if this is large it may be necessary to use more than one jet on a wheel, or to use two or more wheels on the same shaft, to obtain the required speed. Other advantages of the impulse reaction type of wheels are found in the facts that the cases or housings and foundations are light and simple; there are no expensive penstocks or draft tubes to install, and there is no inconvenient means of power transmission and no heavy stone work required.

Turbines have a distinctive advantage under very low heads, because of the large quantity of water which they can use, but under high pressure the speed becomes excessive or destructive. A free jet or tangential wheel may run to the limit fixed by the strength of the material without injury,

FIGURE 5.
42-inch Special Wheel, 350-P. P. Capacity.

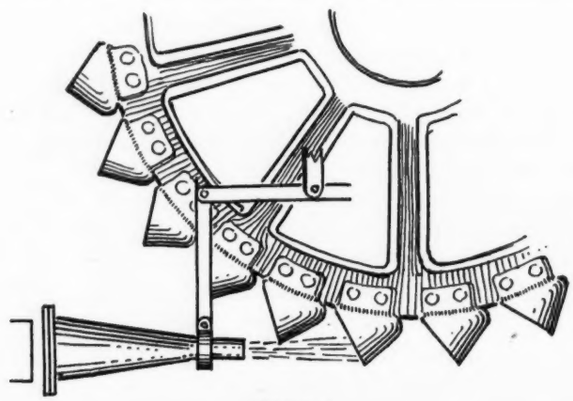

FIGURE 6.
Mode of Applying Jet.

there being no wear except in the bearings. The construction of these wheels indicates that a high efficiency may be obtained when running with a full or reduced water supply, and such has been found to be the case. Buckets are designed for a maximum diameter of stream, without reference to the head, but the only objection to a very much smaller stream would be the disproportion of weights and friction surfaces, an objection which is of very little practical importance. This method is adopted when the quantity of water varies, the minimum stream being often only twenty-five per cent of the maximum. This can be done with no appreciable loss of efficiency, in strong contrast with the turbine, with its variation of twenty per cent, more or less, under varying gates.

In many cases of use, there is no necessity for the adoption of means for confining the speed of water-wheels to the within narrow limits of variation, such as, for instance, in the driving of stamp-mills, rock-breakers, etc.; but in the majority of installations, speed regulation is a prime essential, and especially is it necessary that uniform speed should be maintained in operating electric power generators, in which the load fluctuations are often extremely severe. Such generators impose further necessity for good speed regulation in that the voltage of their output will vary with the speed.

The already enormous use of tangential water-wheels for the operation of electric generators in electric power transmission plants has resulted in the development of means for securing a highly satisfactory degree of speed regulation. If a liberal use of water is allowable, the jet may be deflected from the buckets as the load lessens, thereby applying power sufficient only to carry the load, or, if economy in the use of water is necessary, the area of the jet may be throttled or reduced by means of a cut-off nozzle or a butterfly valve. Various devices for mechanically detecting any variation in speed and applying a corrective therefor are in use, with varying degrees of success, but it is of paramount importance that speed regulation in the operation of a water-wheel should be as perfect as that in steam-engine practice.

Of the multitude of impulse reaction water-wheels on the market, all bear some resemblance to the original "hurdy-gurdy" type, as they differ therefrom solely in the shape of the bucket. It is in this point, however, that the chief factor of the all-important question of efficiency lies; hence it is worthy of more extended consideration. Probably the best presentation of the conditions attending the action of a jet of water striking the various surfaces presented in the different types of tangential water-wheels, is that given by the committee on science and art of the Franklin Institute, which points out that in considering the conditions necessary to a high efficiency in a jet wheel, it will be found that the main conditions are as follows:

1. The jet should enter the bucket without shock and flow over easy curves until its direction is reversed.

2. The surface over which the water passes should be small, to reduce skin friction.

3. The speed of the wheel should be such that the water will leave the bucket without velocity.

The drawings presented in figures 1, 2, and 3 are then given and discussed. Figure 1 shows the action of a jet of water striking a flat plate at right angles. It will be seen that the water divides and shows a tendency to form a wedge of still water, which is what may be termed "dead" water, that is, water which has lost its impelling force. In a wheel having this form of vane there is a tendency to form such a wedge on each vane at every revolution; there can be no smooth flowing of the stream, but a continual turbulence resulting in great loss of energy, and the amount of this will be greater than the loss of part of the energy contained in the water represented by the wedges. It will be seen, also, that the direction of discharge precludes a complete stoppage of the water, the highest theoretical efficiency being fifty per cent, excluding the losses from friction, turbulence, etc.

FIGURE 7.

FIGURE 8.

A Special Type of Wheel for Low Heads.

In the simple curved buckets shown in figure 2 will be found the same condition as to a wedge formation as was shown on the flat plate, the amount of water being even greater. There is, however, a reversal of the stream which allows it to be almost completely checked. This is an important advantage, as may be seen in a comparison of the efficiencies obtained.

Figure 3 shows a third form, in which the wedge has been made a part of the bucket itself, thus avoiding the loss due to the water-wedge and to turbulence. *Impact* has been reduced to a minimum, and the bucket forms part of an *impulse* wheel. In wheels having flat radial vanes or buckets, and a tangential application of the stream, the angle of the impingement varies as the vanes pass through the jet, but there is at all times an *impact*, resulting in a loss. In contrast with this is

the impulse wheel, in which the water enters the vanes or buckets without shock, and is led in the proper path, there being no coercion of the water, but a smooth, regular flow. In the *impact* wheel there is a *blow struck*, while in the *impulse* wheel there is a continuous exertion of energy.

With one noteworthy exception, the only departures that have been made from the three types presented in figures 1, 2, 3, have been in alterations introduced in the shapes of the lips of the cups, in rounding off the angles to give the cups a more elliptical form, or in notching the edge of the lips so that the jet would enter the buckets more unbroken than was possible theretofore. All preserved the dividing wedge, and though the changes made probably resulted in slightly increased efficiencies, none of them embodied any material departures from, or improvements over, tangential wheels of other designs consisting of modifications of the split bucket, inasmuch as the dividing-wedge type of bucket inherently possesses the weak feature that before the jet applies its best efforts it is divided into two entirely separate and distinct parts, each of which acts with entire independence of the other, in the conversion of the energy of the jet into useful work. The obvious consequence of this division is lower efficiency; for the situation is analogous to that presented in steam practice. No mechanical engineer of standing would countenance the installation of two half-unit engines instead of a single whole-unit engine to do one unit of the continuous work. Similarly, no stream should be divided in such a manner that its two halves work independently instead of as a single unit. In other words, a multiplicity of sources of power, collectively operated, inevitably results in inefficiency in operation; hence the fallacy of dividing a jet of water into two streams by throwing it onto the edge of a wedge, if maximum efficiency is desired.

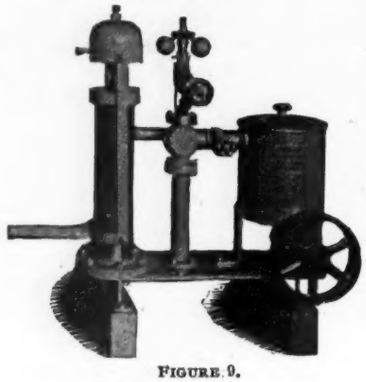

FIGURE 9.
The Water-Wheel Governor.

The noteworthy exception to the general practice just referred to, as well as the chief departure which has marked the development of impulse reaction water-wheels, has been that in which the cups or buckets are placed alternately on the rim of the wheel disc, that is, first on one side and then on the other; the next on the first side and again on the second side, etc., or in the "rights and lefts." This most simple and highly-effective arrangement enables the jet to give its entire and undivided energy to first one bucket and then to another in such a manner that the stream is not broken into two small units with loss in energy resulting therefrom. Figure 4 may serve to make the point more clear. The bucket receiving the jet is shown by the dark outline, and is designed to be of an area practically equaling that of the two halves of the type of bucket shown in figure 3. It will be noted that the bucket in figure 4 takes the entire jet without dividing the stream, that there is no "dead" water in the bucket, and that the discharge follows easy lines and is perfectly free and clear. The next bucket to enter the jet is shown in dotted lines. It is identical with the first, except for the fact that it is placed on the other side of the wheel disc, and that, consequently, it discharges in the opposite side of the wheel.

This arrangement of the buckets in rights and lefts presents a twofold advantage: It increases efficiency by preserving the water of the jet undivided throughout, and it gives discharge of the water on alternate sides of the wheel in such a manner as to absolutely prevent any loss of efficiency from interference or backlash of the waste water. Though the arrangement of buckets has other advantages, all tending to materially increased efficiency, reference to them will be made elsewhere than in these introductory remarks on the general characteristics of tangential or impulse reaction water-wheels.

The preceding matter has discussed the principles underlying the development and operation of jet wheels, and the four figures given may be accepted as typical of the various stages of their growth. The first figure suggests the historical "hurdy-gurdy," now relegated from commercial use to the curiosity shop. The second type represents a class of impulse wheel that some claim has distinct advantage for low heads; the third figure symbolizes the type of the great bulk of jet wheels now on the market, and, as such, marks the beginning and the end of all that has been done in the development of the divided wedge-type tangential wheel of various manufacturers; the fourth figure bespeaks a distinct departure from the preceding practices, and its marked originality is apparent even to the superficial observer. In it is given a diagrammatic representation of the Tutthill water-wheel, the detailed characteristics of which are now described.

The invention of the Tutthill water-wheel resulted after long years of patient investigation, experimentation, and research. It was not brought about by accident, as has been suggested, but through a painstaking study into the conditions under which the ordinary forms of jet wheels were operating, and ample opportunity for doing this was afforded in the water-power plant with which the inventor was connected. The principal losses in efficiency in jet wheels were then attributed (and very properly so) to interference in the delivery of the waste water from the buckets and to the extreme closeness of the buckets, which cut the jet into short lengths, so to speak, and in doing so tended to drive the wheel by the impact of these short lengths of water alone, rather than by the impulse or momentum of the stream plus the constant application of energy due to the head.

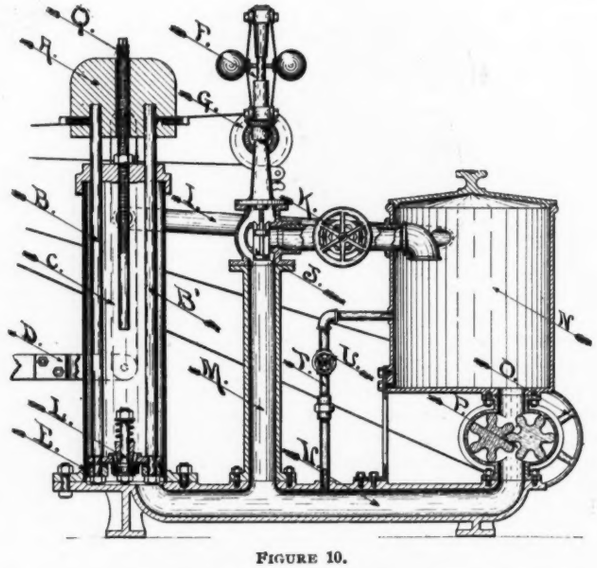

FIGURE 10.
Details of the Governor.

An idle jet wheel of a familiar type was at the plant, and

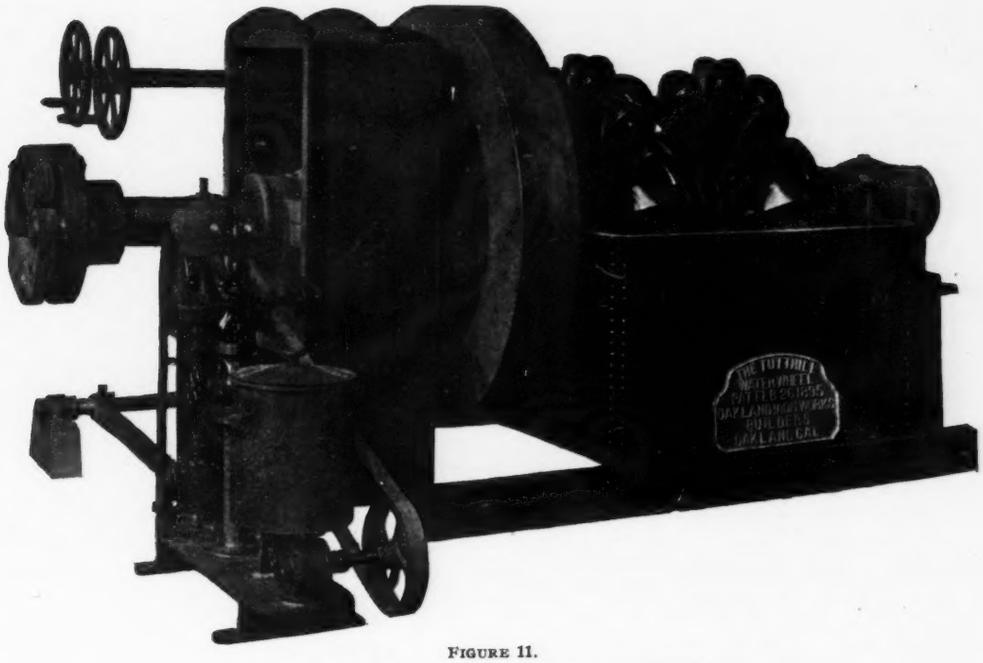

FIGURE 11.
Shop View of a Wheel Set Showing Governor Connections.

it afforded ideal means for experimenting. First, every alternate bucket was taken off the rim or wheel disc, and a greater amount of power could be taken from the wheel when operating under the same jet and head as before, thus establishing the correctness of the conclusion which had been reached. Just whether the gain resulted in improving the discharge or in lessening the number of buckets was yet to be determined; however, subsequent experiments, which need not be related here, demonstrated that each was responsible for a definite portion of the loss. Then came the realization of the fact that the sum of the powers deliverable from the parts of a divided jet must be less than the power deliverable from the undivided jet as a single unit, the truth of which may be easily demonstrated by a simple test. Take a single bucket made on the exact lines of either half of the type of bucket shown in figure 3, and have its depth and area equal to that of the complete bucket of the metal-divided type, that is, the area of the single bucket is to be twice that of either half of the divided bucket. Now, with a given jet under a given head, try the two types of bucket after the manner outlined in figures 3 and 4 respectively; or, what will be still better, mount the buckets of the two types on different wheels of equal diameters, and place the completed wheels on a shaft so that they will be opposed to each other in direction of rotation. Apply to each a jet from equal-sized nozzles under equal head, and the result of the "tug of war" will invariably be that the wheel of the single-bucket type will overcome and drive backward the wheel that is equipped with the divided bucket. This experiment, though it is no criterion of efficiency, has been performed time and again, and has given unquestionable demonstration to the correctness of the opinion that loss of power results from the splitting of a jet.

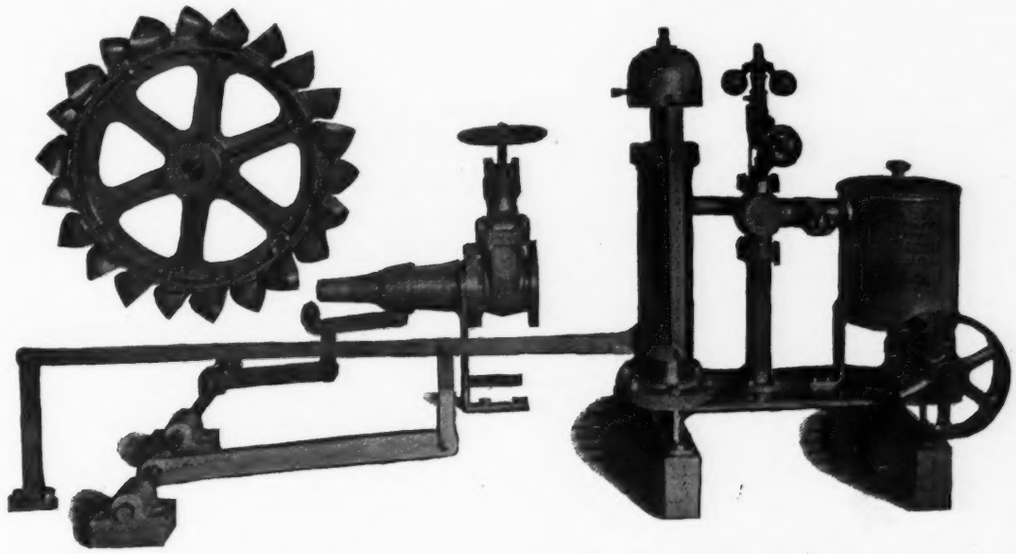

FIGURE 12.
Governor and Connections.

The form of tangential water-wheel which results from the building of a single bucket placed in rights and lefts on a wheel disc—after due consideration has been given to matters of separation between buckets' discharge, arc of jet contact, etc.—is shown in figures 5 and 6, illustrating a Tutthill water-wheel of the standard type, and the method of applying the jet thereto. Some phenomenal results have been obtained from a special type of Tutthill Wheel (illustrated in figures 7 and 8) designed to run under the lower head at the power house of the Nevada County Electric Power Company. The buckets for these wheels are of the peculiarly shallow form so fully shown in the cuts, and the wheels are running in daily service at very high efficiency.

The Tutthill Water-wheel Governor is shown in elevation in figure 9, in sectional detail in figure 10, and in perspective as connected for service in an electric power transmission plant in figure 11. No one but inventors, manufacturers, and sales agents professes to believe that an absolutely perfect water-wheel governor is in existence, hence every new mechanism of the kind that is placed on the market is closely scrutinized in the hope of finding an improvement in some feature on the existing forms of wheel regulator mechanisms. The Tutthill governors not only possess the interesting feature of newness, but they embody the highly-desirable qualification of originality, simplicity, and practical instantaneousness of action. They are all mechanical, and contain no delicate parts necessitating nicety of adjustment or internal vigilance in maintenance. The governors have been subjected to violent changes of load in service, as will be shown, and there is a marked unanimity of opinion among those who are using them, that they are without a superior in any respect.

Their mode of operation will be understood by reference to the sectional drawing, wherein the piston rods *B B*, traveling in the cylinder *C*, carry at their upper ends the weight *A*, and at their lower ends the piston head *E*, while from either side of the weight *A* are long links, one of which is shown in figure 10, by means of which the motion of the pistons is transmitted to the lever *D* controlling the deflector or nozzle cut-off. Separate belts from the water-wheel shaft drive the governor pulley *G* and the pump pulley *O*. The motion of the governor balls *F* is transmitted through a direct rod to the valve *J*, which is under a balance pressure by reason of the passage by means of which the water is allowed to reach both ends of the valve. *N* is a reservoir containing either oil, or water, or both, as preferred, and the liquid therein is kept in constant circulation by the rotary pump *P*, which forces it through the pipe *V*, the upright *M*, and the valve *J*, back into the tank or beneath the piston head *E*, or both, as the exigencies of governing may necessitate. Behind the valve casing is shown an overflow pipe *I* connecting the cylinder *C* with the tank *N*, which is used as a precaution to deliver any liquid that may get above the piston head *E* into the tank. *K* is an ordinary gate valve which may be used, if desired, for shutting down the water-wheels by means of the governor. At *Q* is shown a long screw which may be set by means of a hexagonal lock-nut appearing on the cylinder head so as to throw the relief valve *L* at any desired point, which by cutting out the action of the governor permits its range to be fixed as desired. The pipe *T* is a by-pass, controlling the relaying action of the governor through the manipulation of the valve *U*. When the parts are in the position shown in the diagram, the nozzle is open and the wheel is carrying its full load. The throttling valve *J* being open admits the passage of the entire output of the pump into the reservoir. Assuming now that a portion of the load drops off, the speed will tend to increase, and the change in the position of the fly balls resulting therefrom will close the valve *J* proportionally, thus choking the delivery, which, being incompressible and practically irresistible, finds relief in raising the piston head *E*. This, in turn, raises the lever *D* and throttles the nozzles through the cut-off hoods, or deflecting the nozzle. As the speed of the wheel is restored to normal, the valve *J* also returns to its normal position, which is such that it admits just enough liquid into the discharge pipe to keep the hydraulic pressure in the pipe *M* at such a point as will hold the piston head *E* in the position in which it was placed by the last movement. If, however, an increase of load should now come on, resulting in the lowering of the speed of the water-wheel, the valve *J* will drop proportionately, which will reduce the hydraulic pressure in the pipe *M* by affording a more free outlet, and the piston head *E* will descend by gravity, thus opening up more water on the wheels.

A governing mechanism having more simple basic principles of operation is not to be found, and its extreme sensitiveness is due to the fact that it possesses a relaying principle which is even more effectual than those of the best governors of more familiar and far more complicated forms. It is true that the absence of distinct mechanisms for relaying purposes makes the governor appear to be without the invaluable feature of being able to follow up, or relay, its own actions, but that such is not the case will be understood upon studying the method of operation more closely. It is obvious that the pressure of water from the rotary pump will be delivered with mechanical precision according to any variation in the speed of the main shaft; also that the motion of the fly-ball governor must lag to an appreciable, though small, degree behind any fluctuation that may occur in the speed of the main shaft, because of the time interval that must elapse before the fly-balls will change their positions in response to a change in speed. The pump and governor balls are driven from the same source; the pump gives instant response to a change in speed—the fly ball gives a tardy one; the pressure of water in the pipes *V* and *M* varies instantly with the change of speed in the main shaft, the position of the throttling valve *J* follows a change in speed in the main shaft slowly, and in this situation is found to be a relaying action equal, if not superior, to the best of other forms, and possessing the further great advantage of being of the plainest and most simple form of mechanical construction without the use of delicate or additional mechanisms.

The Standard Underground Cable Company announces the removal of its New York offices, April 30th, to more commodious quarters at No. 56 Liberty street (corner Nassau), and at the new location will be glad to welcome its customers and friends.

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